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ABSTRACT

Researchers disagree not only about the existence or magnitude of sex-related differences in spatial perception, but also about the determinants of such differences. Training in three distinct spatial tasks was provided in an attempt to destablize individual and sex-related differences, while exploring the relative contributions of biological and environmental factors to visual-spatial skill. Undergraduates (N=83) participated in 6 weekly one-hour sessions. Subjects completed four spatial pretests and then were matched on scores and randomly assigned to experimental and control groups. After the experimental group completed three sessions of visual-spatial training in three of the four pretests, all subjects took posttests. Results showed no effects for sex on any of the four posttests, suggesting that males and females benefitted equally and significantly from the training. A comparison of female experimental subjects and male control subjects indicated that training closed the spatial experience gap between the sexes on all tests. Results show that male and female adults may be trained in visual-spatial skills, and that the effects of the training are generalizable beyond the immediate training situation. (NRB)

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Effects of Brief Training on Sex-Related Differences in Spatial Visualization

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EFFECTS OF BRIEF TRAINING ON SEX-RELATED DIFFERENCES IN SPATIAL VISUALIZATION

It has been widely accepted for years that males are superior to females in visual-spatial perception (see, for example, Anastasi, 1968; Maccoby & Jacklin, 1974; Oetzel, 1966), yet recent reviewers (Burstein, Bank & Jarvik, 1980; Fairweather, 1976; Sherman, 1978) conclude that studies in this area are equivocal. For one thing, a number of studies of adult spatial perception have not found sex-related differences (Blum, Fosshage & Jarvik, 1972; Kimura, 1969; Maccoby & Jacklin, 1974; Sherman, 1974; Stericker & LeVesconte, Note 1). Given the reluctance of researchers to report and of journals to publish findings of no significant difference, such findings may well be under-represented in the literature. For another thing, most researchers fail to use statistics that reflect the actual size of the sex-related differences they report (Burstein et al., 1980; Jacklin, 1979; Sherman, 1974, 1978; Tresemer, 1975). There is also considerable question about the number and nature of the factors being measured by "spatial" tests.

Researchers disagree not only about the existence and/or magnitude of the sex-related difference in spatial perception, but also about the determinants of the difference. There are proponents of the X-linked heritability hypothesis (e.g., Hartlage, 1970; Stafford, 1961), of hormonal explanations (e.g., Broverman, Klaiber, Kobayashi, & Vogel, 1968), of brain lateralization theories (e.g., Buffery & Gray, 1972), and of sociocultural theories (e.g., Goldstein & Chance, 1965; Nash, 1975; Sherman, 1978). Reviewers (Burstein et al., 1980; Sherman, 1978; Vandenburg & Kuse, 1979) generally conclude that the biological and environmental factors responsible for the development of visual-spatial skill are quite complex and probably interactive.

Sherman has explored the relationship of a number of environmental variables to sex-related differences in visual-spatial skill (1967, 1974, 1978, 1979; Sherman & Fennema, 1977, 1978). She hypothesizes that cultural sex-role patterns result in different childhood experiences for girls and boys and that these affect the development of spatial perception. Boys, she suggests, spend more time than girls do in activities which give them spatial practice (e.g. model construction, block building, playing catch, throwing darts).

To explore the relative contributions of biological and environmental factors to visual-spatial skill we attempted to improve the skill by training and thereby to destabilize individual and sex-related differences. Instability in individual differences has been thought to argue against high heritability (Vandenberg, 1975). If females are more likely than males to lack relevant spatial practice, then given sufficient training and practice, they might be expected to improve their spatial visualization more than males. Although a number of studies have established that spatial performance can be improved by practice or training (Blade & Watson, 1955; Brinkman, 1966; Connor, Serbin & Schackman, 1977; Connor, Schackman & Serbin, 1978; Goldstein & Chance, 1965; Vandenberg, 1975), the study presented here is unique in its goal of providing training in three distinct spatial tasks, rather than just one. We also provided a measure of generalization, which, with the exception of Connor et al., (1978) has not been done by others. We had several purposes in mind for this study:

1) To show that spatial visualization skills are trainable,
2) To assess whether our training effects would generalize to a test on which no training would be given,
3) To show that both men and women could improve their spatial skill and

that women could improve more than men, thereby reducing or eliminating any pre-test sex-related difference that might occur,

4) To provide information about the magnitude of our effects,

5) To explore more specifically how successful the training would be in equalizing the prior experience of males and females in spatial visualization,

6) To provide information about the commonality of the several spatial tests used in the research.

Methods

Subjects

Subjects were 50 female and 41 male introductory psychology students who volunteered for extra course credit and monetary payment. The 6 hour-long sessions, spaced a week apart, consisted of 1) collection of background data and explanation of the study. 2) pre-testing, using four standard spatial tests, after which subjects were matched on pretest scores and randomly assigned to experimental and control groups, 3), 4), and 5) visual-spatial training for experimental subjects only, and 6) posttesting of all subjects.

Of the 91 pretested subjects, four dropped out during the training or the posttest, which left 87 subjects for analysis. Of these, four subjects over age 35 were also dropped, to eliminate the confound of age effects.

The four tests of spatial skill were:

1. Space Relations test of the Differential Aptitude Tests (DAT) (Form S: Bennett et al., 1974);
2. Group Embedded Figures Test (EFT) (Oltman, Raskin, & Witkin, 1971);
3. Vandenberg-Shepard Mental Rotations Test (VAN) (Vandenberg, Note 2) (This test is an adaptation by Vandenberg of the Shepard-Metzler

(1971) mental rotation task); and

4. Space Relations Test of the Primary Mental Abilities (PMA) (Thurstone, 1965).

Practice and training were provided on the first three, and the PMA, on which no training was given, was the measure of generalization. The DAT and the VAN were both split to provide equivalent forms for the pre- and posttest. The EFT was expanded by the addition of items from the Hidden Figures (Educational Testing Service, Note 3) and used in toto for both pre- and posttest, since other Hidden Figures items were used for training.

Training Procedure

Subjects were seated at tables of four persons, two of whom had scored above and two of whom had scored below the median on the pretest. This was done so that the spatially more successful could coach the spatially less successful during the sessions. Each 60-minute session was divided into three mini-sessions, so that approximately 20 minutes were devoted to training on each of the three tests. Each mini-session began with a brief (3-4 minute) quiz containing items either identical or similar to items from the pretest. Following the quiz, correct answers were presented, and free practice with the items began. During this time subjects worked on items they had missed, discussing difficult items with others who had got them right. High scorers were especially encouraged to verbalize their strategies for solving the items and to help the others as much as they could.

During each practice period learning aids were also available to the subjects. These included large paper cut-outs of about half the DAT pretest items which could be manually folded into the intended 3-dimensional stimulus figure, transparencies of embedded figures which were presented via overhead projector so that the hidden simple figure could be gradually exposed by

overlay transparencies, and large styrofoam models (14-16 inches in length) of all the VAN stimulus figures, which subjects could manipulate and compare to stimulus items.

Results

Means and standard deviations for all groups for all tests as well as for the average of the pretests and the average of the posttests are presented in Table 1. Pretest Average was computed by converting each individual pretest score to a standard score based on the total sample, adding a subject's four pretest standard scores, and dividing by four, then computing an average

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Insert Table 1 about here

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of these scores for the group. Posttest Average was computed in similar fashion from posttest standard scores. Group means for experimental and control subjects, both as a whole and for each sex, did not differ significantly on any pretest, indicating that the matching procedure succeeded in making the groups equivalent in spatial skill prior to the training period. On the other hand, the significant sex-related difference in spatial skill frequently reported in other research appeared here (See Table 2).

Insert Table 2 about here

Effects and generalization of training.

To assess the effects of sex and training on visual-spatial skill, we subjected the four dependent variable posttest scores to a 2 (sex) by 2

(group) multivariate analysis of variance using pretest scores as covariates. This analysis yielded a significant multivariate effect for group, showing that performance on the posttest was significantly improved by training (See Table 3). Univariate analyses of variance indicated that this overall effect derived specifically from a significant group (that is, training) effect in each of the four posttests.

Insert Table 3 about here

Since the PMA was the "untrained" test, the significant group effect here shows that training effects did generalize beyond the immediate training situation.

Sex and Interaction Effects

There was no effect for sex on any of the four posttests, meaning that male and female scores on the posttests did not differ significantly after the male pretest advantage had been statistically controlled. This shows that males and females benefitted equally and significantly from the training. We found no group-by-sex interactions on any of the tests.

Size of Effects

Recognizing that results can be statistically significant without being large enough to be meaningful, we computed omega squared or eta squared statistics for each of our significant effects. Both these statistics provide a measure of the magnitude of an effect, by showing what percent of the variance in performance can be accounted for by the variable in question (Friedman, 1967; Hays, 1963,1973).

Eta squared statistics (Table 3) indicate that the three hours of training account for 15% of the variance in the four posttests combined, and

between 9 and 35% of the variance in the four individual posttest scores. Specifically, training was responsible for 9% of the variance on the DAT, 12% on the PMA, 21% on the EFT, and 35% on the VAN.

Did training equalize male and female levels of skill?

Pursuing the argument that males surpass females on spatial tests in large part because males have had more experience of the sort which provides practice and training on spatial skills, we wanted to assess the extent to which our training helped to close the spatial experience gap between the sexes. Accordingly, we compared Male Controls (MC) and Female Experimentals (FE). There was a significant sex-related difference in favor of males prior to the training on three of the four tests and on the average of the four pretests (Table 4-A). Comparison of FE's with MC's on the posttest scores (Table 4-B) shows no significant difference between Male and Female means for any test.

Insert Table 4 about here

Finally, we tested the difference in pretest-posttest change score means of MC's and FE's. The males, of course, had had one hour of pretest practice, whereas the females had had an hour of pretest practice and three hours of training. The female mean gain was greater than the male mean gain on three of the four tests and on the four-test composite (See Table 4-C). Calculating omega squared statistics we estimated the amount of this difference in improvement accounted for by the training. None of the difference on the DAT, but 7% of the difference on the PMA, 14% on the EFT, 20% on the VAN, and overall 12% on the composite, can be accounted for by the three hours of training given to the female experimentals. Thus females with one hour of

practice and three hours of training improved significantly more on most posttests than did males with only one hour of practice. This greater improvement means that the experimental females came from behind and ended neck and neck with the control males. Training, then, did close the spatial experience gap between the sexes on all tests, including the untrained PMA, and the four-test composite. In view of the substantial difference favoring males on the pretests (Table 4-A), the finding of no difference on the posttests is noteworthy.

Comparability of tests

Although a fuller exploration of the components of spatial skill based on these data will appear in another report (Stericker & LeVesconte, Note 4) we present in Table 5 all inter-test correlations, to indicate the extent of overlap of the tests. Most correlation coefficients are in the moderate range, suggesting the tests are measuring some factor(s) common to the four tests and some which may be specific to each test.

Insert Table 5 about here

Discussion

Our results show clearly that visual-spatial skill is trainable in both female and male adults, and that the effects of our training generalized beyond the immediate training situation.

One interpretation of these findings is that training not only improved the spatial skill of subjects but also improved their level of motivation. People may fail at tasks not so much because their skill is inadequate as

because they believe they cannot do the tasks. The training described in this study constantly emphasized to participants that continued effort was the key to improvement, and that even very low scorers could improve if only they persisted in their efforts and accumulated more spatial practice. We believe that this emphasis helped to change the subjects' attitudes toward spatial tasks in such a way that they perceived their past difficulties not as evidence of their lack of ability but simply as the result of insufficient practice and/or effort.

Even though our expectation that any sex-related differences found on the pretests would be eliminated on the posttests was not realized for any of the four tests, it is important that males and females improved equally on all four tests. If the sex-related differences had shrunk or disappeared after training, the view that males are at or near the asymptote of their ability, whereas females are not, would have been supported. The present results suggest that neither sex is performing near the asymptote of its ability, and to equalize the advantage of spatially-related practice which males presumably have had will require more extensive training than was given here.

We believe our project was ambitious, in that we attempted to close the performance gap between females and males on four separate spatial tests after only four hours (including pretests) of training and practice. Our limited success in this venture is encouraging, yet it impresses us that the gap in spatially related experiences between males and females is considerable. In addition, the instability of the scores on tests designed to be highly stable (some subjects doubled their scores) argues against a biologically determined trait and for the view that spatial skill is to a large extent learned. The view that spatial skill is innate and unchangeable is challenged by these results.

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Table 1

Means and Standard Deviations by Sex and Group

	FEMALES			MALES			ALL	ALL
	Experimental	Control	All	Experimental	Control	All	Experimentals	Controls
	(N=24)	(N=21)	(N=45)	(N=21)	(N=17)	(N=38)	(N=45)	(N=38)
PMA PRETEST	38.1 (11.2)	41.3 (13.2)	39.6 (12.2)	46.0 (11.6)	46.1 (12.5)	46.1 (11.8)	41.8 (11.9)	43.4 (13.0)
PMA POSTTEST	48.0 (10.4)	43.3 (15.6)	45.8 (13.1)	53.9 (9.4)	51.6 (10.4)	52.8 (9.8)	50.7 (10.3)	47.0 (14.0)
DAT PRETEST	16.8 (5.2)	15.9 (6.1)	16.4 (5.6)	20.9 (5.0)	21.9 (6.1)	21.3 (5.5)	18.7 (5.5)	18.6 (6.7)
DAT POSTTEST	21.9 (6.4)	18.1 (6.9)	20.1 (6.8)	26.3 (7.1)	25.4 (6.0)	25.9 (6.6)	23.9 (7.0)	21.4 (7.4)
EFT PRETEST	12.2 (5.3)	10.0 (6.0)	11.2 (5.7)	16.4 (5.5)	16.8 (6.5)	16.6 (5.9)	14.2 (5.8)	13.0 (7.1)
EFT POSTTEST	20.5 (8.3)	14.0 (8.0)	17.4 (8.7)	26.0 (8.3)	20.8 (6.16)	23.7 (7.9)	23.1 (8.6)	17.0 (8.1)
VAN PRETEST	21.2 (4.8)	21.0 (5.2)	21.1 (4.9)	25.7 (5.8)	23.2 (8.2)	24.6 (7.0)	23.3 (5.7)	22.0 (6.7)
VAN POSTTEST	30.4 (6.2)	24.8 (4.7)	27.8 (6.2)	35.6 (3.4)	26.5 (8.0)	31.5 (7.4)	32.8 (5.7)	25.5 (6.3)
PRETEST AVERAGE [a]	-.28 (.65)	-.35 (.72)	-.32 (.67)	.40 (.65)	.35 (.88)	.37 (.75)	.03 (.73)	-.04 (.86)
POSTTEST AVERAGE [a]	-.02 (.71)	-.62 (.84)	-.30 (.82)	.60 (.65)	.05 (.73)	.35 (.73)	.27 (.74)	-.32 (.85)

[a] Based on standard scores for each of four tests.

TABLE 2

Male and Female Means

On Each Pretest and on Average of Four Pretests

Test	Mean (S.D.)		t	ω^2
	Females	Males		
PMA	39.6 (12.2)	46.1 (11.8)	2.41*	.06
DAT	16.4 (5.6)	21.3 (5.5)	4.03**	.16
EFT	11.2 (5.7)	16.6 (5.9)	4.37**	.18
VAN	21.1 (4.9)	24.6 (7.0)	2.60**	.09
PRETEST AVERAGE[a]	-.32 (.67)	.37 (.75)	4.35**	.18

*$p < .01$
**$p < .001$
[a]Based on standard scores for each of four tests.

TABLE 3

Effects of Sex and Training on Four Spatial Tests

Dependent Variable	Source	df	F	p	eta^2
Four Posttests Combined	Group (G)	4,72	14.20	.0001	.15
(with 4 pretests	Sex (S)	4,72	0.13	--	--
covariate)	G x S	4,72	0.17	--	--
Individual Posttests:*					
PMA	Pretests	4	137.38	.0001	.65
	Group	1	11.36	.0001	.12
	Sex	1	0.0	--	--
	G x S	1	2.10	--	--
DAT	Pretests	4	48.81	.0001	.65
	Grpup	1	8.15	.01	.09
	Sex	1	.42	--	--
EFT	Pretests	4	65.30	.0001	.65
	Group	1	21.56	.0001	.21
	Sex	1	.01	--	--
	G x S	1	.17	--	--
VAN	Pretests	4	26.57	.0001	.57
	Group	1	44.46	.0001	.35
	Sex	1	.05	--	--
	G x S	1	2.08	--	--

* Also with all four pretests covariate

Table 4

Comparison of Female Experimentals with Male Controls

Test	Group	n	A: Pretest Means			B: Posttest Means			C: Pretest-Posttest Differences		
			Mean	t	ω^2	Mean	t	ω^2	Mean	t	ω^2
PMA	Female Exp.	24	38.08		.08	47.95	1.10	.00	9.88	2.07*	.07
	Male Con.	17	46.06	2.14*		51.58			5.53		
DAT	Female Exp.	24	16.75			21.88			5.13		
	Male Con.	17	21.88	2.89**	.15	25.41	1.79	.00	3.53	1.06	.00
EFT	Female Exp.	24	12.21			20.50			8.29		
	Male Con.	17	16.76	2.45*	.11	20.82	.13	.00	4.06	2.92**	.14
VAN	Female Exp.	24	21.21			30.38			9.17		
	Male Con.	17	23.18	.96	.00	26.47	1.77	.00	3.29	3.35***	.20
COMPOSITE	Female Exp.	24	-.28			-.02			.26		
	Male Con.	17	.34	2.66**	.13	.05	.29	.00	-.30	2.55**	.12

*p < .05
**p < .01
***p < .005

Table 5

Intercorrelations[a] Among Pretests and Posttests for All Subjects

	PMA1	DAT1	EFT1	VAN1	PRETEST AVERAGE[b]	PMA2	DAT2	EFT2	VAN2	POSTTEST AVERAGE[b]
PMA1										
DAT1	.52									
EFT1	.44	.74								
VAN1	.47	.48	.28							
PRETEST AVERAGE[b]	.77	.87	.78	.71						
PMA2	.84	.58	.56	.44	.77					
DAT2	.63	.81	.69	.48	.83	.68				
EFT2	.44	.62	.81	.34	.86	.60	.72			
VAN2	.38	.43	.41	.60	.57	.56	.54	.56		
AVERAGE	.68	.73	.73	.55	.86	.84	.88	.86	.79	

Pretest Correlations

Posttest Correlations

[a] All correlations are significant at $p < .01$

[b] Based on standard scores for each of four tests.